

DIGITAL SCULPTURE: TECHNICAL AND AESTHETIC CONSIDERATIONS APPLICABLE TO CURRENT INPUT AND OUTPUT MODES OF ADDITIVE FABRICATED SCULPTURE

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ABSTRACT

This article examines the synergy between aesthetic and technical issues surrounding current input and output modes applicable to digital sculpture built by means of additive fabrication technologies. The scope is limited to select sculptural aspects that either transcend, question or fall short when measured against traditional manufacturing and aesthetic modes. Presented are a range of technical as well as aesthetic aspects that have impacted on this “new form” of sculpture delivery. It is indicated that irrespective of current strengths and weaknesses, for the evolving sculptor, an interactive creative partnership between technologies equally positions this “new form” of sculpture delivery as a leading role player towards defining a new digital aesthetic.

Keywords: Digital Sculpture, Additive Fabrication, 3-D CAD, Aesthetics

1. INTRODUCTION

Overall, technological developments increasingly reflect that as a medium, digital sculpting has surpassed traditional manufacturing boundaries, allowing for the design and build of complex sculptural forms that facilitate aesthetic uniqueness. The design and manufacture thereof is, however, reliant on an interdisciplinary creative partnership between artist and engineer, where technical and creative problem solving merge from the onset of an idea. Although recent years have witnessed several technological advances in the 3-D design and build of digital sculptures, most of these 3-D build technologies are engineering-based in their RPM (Rapid Prototyping and Manufacturing) mechanical applications. More accommodating to the artists needs are developments in 3-D free-form computer-aided design (CAD) software applications that progressively allow for innovative artistic intervention during the design input and conceptual planning stages of digital works. The challenge for most 3-D CAD product developers is therefore to facilitate maximum artistic intervention and therein address the ongoing need for human-connectedness during the creative process. Maintaining human-connectedness for the sculptor forms a fundamental creative element from incubation of idea through to the development phase of a conceptually motivated artwork.

Michael Century's (1999) publication titled *Pathways to Innovation in Digital Culture* examines the generation of technological innovation as hybridised

cultural research in which he cautions against too much exposure to digital technology as it could lead to a loss of criticality in the arts because of technologies automating as opposed to acting as creative partners. Irrespective of this caution, artists are located in a time where technologies and new media accelerate through using; it is therefore the artists' responsibility to maintain a balance between form, content, technique and idea in order to establish the said creative partnership. With similar cautionary intensity, Lovejoy (2004) claims that artists wishing to stay entrenched within a traditional fine art discourse will remain confronted with challenging high/low artistic boundaries arising from the merging of fine art with commercial design production. Therefore, to engage in the technology, the sculptor is required to free him or herself from a "medium specific" process to explore this elusive dematerialised artistic medium in order to forge creative partnerships within art and technology paradigms.

For the sculptor, the layered manufacturing additive fabrication (AF) technology application is regarded as a new artistic form. AF technology has therefore contributed to redefining the function and reception of sculpture on both technical and aesthetic levels. Digital sculptor Keith Brown, founder member of FasT-UK (Fine Art Sculptors and Technology in the United Kingdom), states that digital sculpture has led to a "new order" of sculptural object, a paradigm shift, and the emergence of a new digital aesthetic (Duffield, 2001). In this article, the current technical status and the impact of aesthetic issues surrounding digital sculpting is explored as a technology-based creative partnership, towards defining a perspective on this "new order" of sculptural delivery.

2. DIGITAL SCULPTURE AS MEDIUM

Digital sculpting encompasses the creative development of an idea in virtual space, with the work being realised in physical space i.e. AF technologies. Author and digital sculptor Christian Lavigne (1998) defines digital sculpture as a linkage of the following three complimentary activities:

- Creation and visualisation by computer of forms or constructions in three-dimensions.
- Digitizing real objects and their eventual modification made possible by computer calculations.
- The production of physical objects by numerically controlled machines that are used to materialise synthetic images.

Digital media often lack narrative content as a result of their being technological vehicles. In an attempt to categorise this phenomenon, the medium has been compared to the minimalist sculptures produced during the 1960s, where the modalities of technology become the substance of the work which is modelled, manipulated and juxtaposed with the viewer, to create meaning (Penny, 1999). Edward Shanken (2002) expands on this form of

sculpture by stating that computer technologies have played a unique role in the aesthetic value of sculpture delivery, due to advances in technology providing tools that enable artists to cross-examine the conventional materiality and semiotic complexity of art objects that were previously unavailable.

However, William Ganis (2004) questions the conceptual facility of digital sculpture as an output medium and states that it could not be relied on for content or quality artistic forms until such time that technology develops. As mentioned above, this line of thought can be challenged with the knowledge that when producing digital sculptures using CAD design and AF processes in many cases, as with the minimalist sculptures produced in the 1960s, the technological combination becomes the content of the work and the conveying of narrative content possibly becomes a secondary issue.

Digital sculptors work in a medium of repetition without an original object and have the option of unlimited duplication. It can therefore be argued that such sculptures deny the sculpted material's "aura" of authenticity, the loss thereof first sited by Walter Benjamin (1969), since the electronic data used to develop digital works is easily transported via the internet and can be accurately reproduced by any RP station. The ubiquitous nature of this medium constantly stimulates debate around issues of authorship, originality and copyright, addressed as aesthetic concerns further on in this article.

Several digital sculptors have emerged producing works that stand on their own as "masterpieces" within both the conceptual and technical boundaries of digital sculpture. After reviewing the working methods of several distinct sculptors i.e. Carlo Sequin, Michael Rees, Christian Lavigne, Mary Visser, Lionel Dean and Bathsheba Grossman, findings revealed that in their works all employed CAD as a fundamental tool in their procedural shape generation, thus indicating a high value for CAD as input mode. The same high value was displayed with all making use of various standard output AF build technologies. Shortcomings in their technological applications indicated a restricted use of varied input devices (i.e. haptic devices, 3-D scanning, data gloves, virtual headsets), reasons which could possibly be linked to cost or accessibility. Each artist has however explored the advanced technology of 3-D colour printing as an output mode at some stage or other but none approaching it as a specialist medium, possibly due to current inadequate data translations from CAD to RP machines. The majority of the reviewed artists make limited use of narrative concepts as aesthetic element. Comparatively this displays a lesser overall representational modality with regard to conceptual meaning. For most, a strong focus remains on the intersection between abstract form and mathematics as a conceptual departure point, therefore indicating a high non-representational conceptual modality. One could therefore deduce that there is a growing need for all aspects of the technology to accommodate a representational as well as an abstract non-representational approach to this "new form" of sculpture. At

present, abstract non-representational sculpted form remains a more predominant mode of 3-D digital aesthetic delivery, therefore questioning digital technologies' role as narrative conceptual creative partner.

3. CURRENT 3-D INPUT AND OUTPUT MODES

3.1 Three-dimensional design input modes

There are several 3-D CAD programs available on the market, e.g. Maya, Form Z, Solid Works, 3-D Studio Max, ArtCam and Rhinoceros. The latter is an inexpensive, easy and popular software program applicable to the sculptors' free form design needs. Most 3-D CAD programmes support the .STL (Standard Triangulated Language) suffix needed for RP builds. Programs based on NURBS (non-uniform rational B-Splines) geometry are suitable for 3-D designers who work with free-flowing form. NURBS-based software programs are therefore ideally suited to the design and build of complex sculptural models that explore the synergy of form and content. For the sculptor a benefit of 3-D CAD is that it allows for the pre-examination of form and structure, complex macro and micro viewpoints in a weightless environment prior to the realisation in physical space.

The 3-D scanning of an object by way of reverse engineering is an input mode of generating virtualised object models by measuring data such as the shape and texture of 3-D form. The type of scanner (probe or laser) and its current technological advancement normally determines restrictions. The recent launch of Z Corporation's 24-bit colour mobile ZScanner® 700 CX presents potential for the virtual recording of 3-D artworks destined for digital database development and similar recording applications. However, at present this scanner offers a low texture resolution of 250 dpi, which presents difficulty when scanning detailed colour texture resolutions.

The loss of human-connectedness through automation will remain a limitation within this new artistic form until computer technology input modes successfully evolve to replicate the physiology of human sensory touch. In an attempt to break free from the mouse-driven CAD input approach, the development of a less constrained, more naturalistic input mode is the innovative "haptic device" a design interface developed by SensAble Technologies (Figure 1).



Figure 1: Omni PHANToM haptic device (SensAble Technologies, 2007)

The designer's hand is able to move around the illusionary object, virtually feeling its shape while viewing and manipulating it on the computer screen. The system is able to mimic the sculptor's pushing and pulling of the modelling surface and offers a range of multi-resolution modelling tools, which enhance the modelling of form and 3-D texture. Irrespective of the significant developments of this system, it still operates on a single "patch" area manipulation, which demonstrates a limitation when compared to the physiological sensory application of the human hand. Developments surrounding the "multi-patch" manipulation of the NURBS surface and the addition of more complex modelling tools present research potential that will aid sculptural applications and therefore facilitate the conceptual design process.

Carlo Sequin (2005), computer science professor at Berkeley, University of California, proposes that as technological and mechanical aspects of design improve, 3-D CAD tools need the most development with the speed of real-time interactivity during the early conceptual design phase to ensure that the designer's creative thinking process is not hindered. The CAD input environment will therefore be at its most effective once the artist can process conceptual ideas at the real-time speed with which they are generated in the creative mind. Renewed developments of design input modes facilitate a more fluid and flexible human-centred digital design environment. In turn, this enhances the overall interactive conceptual design process and therefore shortens the development cycle of producing aesthetically distinct 3-D models.

3.2 Three-dimensional additive fabrication output modes

Recently, engineering-based AF technologies have prominently infiltrated the 3-D build of complex computer-designed functional form. The accelerated impact of this technology is evident in the unique functional organic sculptural forms produced by UK product designer Lionel Dean (www.futurefactories.com). AF technologies allow Dean to explore the adaptation and personalisation of complex creative form for an emerging Rapid Manufacturing (RM) market. Michael Rees (1999), a USA sculptor working with AF, has termed this accelerated technology "Desktop manufacturing", which clearly depicts the accessible potential that this technology represents. The current development of less expensive desktop 3-D RP modellers (uPrint) developed by Stratasys Inc. are able to provide quick feedback during the conceptual design process, a uniqueness that transcends present artistic manufacturing boundaries.

AF technologies vary in cost, process and material and constantly face technological advances. Implementing rapid changes in technology mostly presents financial limitations for the sculptor. However, the direct Laser Sintering (LS) of metals (titanium, bronze, bronze-nickel blend, steel) proves to be the way forward for the metal-working sculptor as this system can be

used for a broad range of applications: investment casting, direct model building, hard and soft tooling. Stereolithography (SLA) is a finer build process best suited to detailed form, wherein liquid resin cures by exposure to ultraviolet light. An alternative to LS materials is the slower build Fused Deposition Modelling (FDM) process, which feeds Acrylonitrile Butadiene Styrene (ABS) thermoplastics and an investment casting wax through a narrow, heated nozzle, which then fuses over the base plate. At present, the post-processing of the irregular layered surface finish (evident in cheaper builds) and option to post-apply colour presents inexpensive and accessible aesthetic solutions for reintroducing the sought-after creative element of maintaining human-connectedness.

Most RP bureaus are more or less equipped with the above machine types and their various build material options. Nonetheless, with the accelerated rate at which the technology is advancing, some of these machines have already been updated with faster build speeds, larger build platforms, reduced pricing and ground-breaking material properties such as the recent Digital Light Processing (DLP) of photopolymer material as an alternative to the widely used LS powders. At this stage, the larger interest is RM and whether build material properties are able to adequately develop in order to meet RM industry expectations (Wohlert, 2006b).

4. HYBRIDISATION OF NEW TECHNOLOGY AND TRADITIONAL ART PROCESSES

Through an established collaborative effort computer professor Carlo Sequin and abstract geometric wood sculptor Brent Collins have been exploring the hybridisation of computer technology and the traditional art process by generating various 3-D CAD visualisations of complex structures. The carved, twisted, seven-story, ring, wooden sculpture “Hyperbolic Heptagon” (Figure 2a) initially built by Collins and later a combined digital exploration thereof by Collins and Sequin (Figure 2b) further stimulated the design of sculptures with much higher complexity, i.e. “Heptoroid” (Figure 3). This was made possible by Sequin, who developed a specific computer program (Sculpture Generator) that calculated each complex sculptural configuration as commercial 3-D CAD tools lacked the convenient procedural capabilities. The developed computer program transcended the initial expectation of simply achieving a means to a speedy template design for the complex geometric wooden sculptures, and instead facilitated the development of a complex design structure that would not have been possible without the aid of the computer. Sequin (2005) refers to these programs as his “[...] virtual constructivist “sculpting tools” and concludes, “[...] the computer thus becomes an active partner in the creative process of discovering and inventing novel aesthetic shapes”.

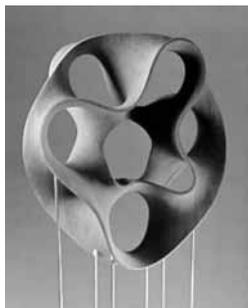


Figure 2a:
Hyperbolic Heptagon,
B Collins

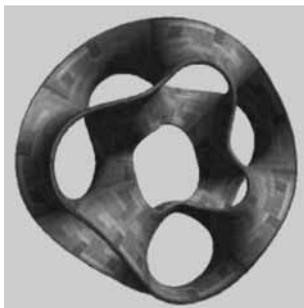


Figure 2b:
Hyperbolic Heptagon
C Sequin & B Collins



Figure 3:
Heptoroid,
C Sequin & B Collins

The hybridisation of new and traditional technology is evident in the direct FDM build of ABS plastics, wax expendable models, LS powder builds and SLA Accura® Amethyst® resin, which can be burnt out during the traditional investment casting process with limited mould defects. The ceramic shell investment of RP master built models is particularly suited to complex forms where it would be difficult to make a traditional flexible rubber mould from an existing master pattern for the casting of a secondary wax. However, the ceramic shell moulding and burnout technique of these RP built models for the investment casting of metals remains a delicate process and an area in need of additional research. Problems occur as a result of the following: residues left within the mould cavity, mould damage due to the expansion of the various material builds during burnout, pattern distortion as a result of warm weather, incomplete bonding of shell layers and surface defects due to pattern porosity (Dickens, Stangroom, Greul and Holmer, 1995). Direct RP methods of arriving at a model are still regarded as more costly than traditional moulding and wax pouring of secondary models currently used by most foundries. However, the disadvantage of traditional indirect model reproduction via flexible rubber mould is that it is restricted by complex form.

The above indicates how the hybridisation of new technology and traditional art processes remain technical research areas of varied potential that currently not only facilitate the artistic manufacturing process, but also predict that in time the cost-effectiveness of RP technology will allow this technology to become accessible to many.

5. SCULPTURE: TECHNICAL LIMITATIONS AND DEVELOPMENTS IN 3-D CAD AND ADDITIVE FABRICATION TECHNOLOGIES

The medium of digital sculpture and the RP build thereof when measured against traditional “sculptural” characteristics presents varied technical limitations that still need to be overcome. As mentioned a key development is the ability to design intertwined convoluted 3-D form beyond “sculptural” expectations as the RP build process is unimpeded by complexity of form. The

sculptor is therefore presented with a weightless platform to explore “sculptural” within a “new paradigm” irrespective of the technical limitations encountered with CAD software programs, colour, surface finish, durability, scale or cost.

Software developer and product analyst Suchit Jain (2006), at Solid Works Corporation, claims that introducing conceptual design tools into the software system of automated 3-D CAD technology is the answer to reducing the current time spent on design analysis, as 60%-70% of product development is spent on the concept design cycle. Currently most CAD designers still prefer to pre-sketch their concepts by hand or to a lesser extent utilise digital conceptual analysis tools. These however are not able to integrate with the 3-D CAD design environment and create real-time delays therefore restricting creative innovation. For the artist this presents a concern as during the conceptual design phase, an unhindered cycle of creative recursion remains a key element in producing innovative concepts and therefore innovative RP builds.

Three-dimensional colour printing and additive fabrication remain areas of research that have yet to develop to their full potential. The most recent commercial colour RP system introduced by Z Corporation is the ZPrinter® 650, which can build parts in monochrome, multicolour and true black modes at 600 x 540 dpi resolutions. For technical application Z Corporation has developed the ZPR binary file format that supports colour and texture maps unlike the common .STL file format used to move CAD data to RP machines which do not read colour data (Wohlers, 2006a). The use of colour for an artist generally creates meaning, content and nuance, which, unlike for an engineer, the inclusion thereof is often essential to the work (Rees, 1999). Therefore, the constraints surrounding the development of accessible high-resolution 3-D colour printing can be regarded as a limitation, seeking solutions for the long-term development of digital sculpture.

The mineral or geological quality detected on most inexpensive RP builds is a surface property of the layer building technology. To overcome this surface finish problem, most minimal detailed RP builds undergo either tumbling or sandblasting to smooth out the surface. A limitation linked to post-processing the build is the risk of damaging the model, particularly the starch-based powders, as they are very brittle. Research opportunities therefore exist in areas to improve model quality and factors that would influence these improvements (Dimitrov, Wijck, Schreve and De Beer, 2003). Surface finish as a build limitation too impacts on the CAD NURBS-based user; since on-screen 3-D objects are digitally created using smooth surfaces, which then due to the lack of an adequate translator from NURBS to .STL, the smoothness during the RP build is compromised (Wohlers, 1992). Various RP software translators are used for the pre-build repairing of unstable or defective file parts. These translators also assist with loading and manipulating the position of the model on the build platform. The correct

model positioning in relation to the RP machines' laser beam is able to improve a rough surface finish or prevent the form from “curling”.

Presently metallic materials are regarded as the stronger and more durable prototyped material. High strength and durability tests forming part of a comparative analysis between various metal RPM systems using Direct Metal Laser Sintering (DSLM), Selective Laser Sintering (SLS) and Selective Laser Melting (SLM) processes overall revealed that high strength is determined by low porosity and high density of material builds. These properties in turn affect the dimensional precision and overall surface finish of the product. Results showed that although the SLS metal processes proved rather slow and costly, it was found to be more durable, accurate and a reliable future technology to develop (Ghany and Moustafa, 2006).

The RP build of a maquette assists in eliminating many unforeseen aesthetic and structural problems that may arise, and therefore presents the sculptor with a more accurate preview of the final product. A sculptor needing to produce a larger work would be confronted with having to build a model in sections due to size limitation of the various RP machine build platforms. For a large sculpture this limitation would possibly increase the number of builds, which in turn increases the build and post-processing time and therefore cost. Dimitrov, Schreve, Taylor and Vincent's (2007) concluding test results on a series of large plastic and metal built components found that the build accuracy and surface finish of components did not measure up to conventional methods; however, they were not too far off the mark either. Increased scale of the plastic builds was restricted to a polyurethane material; however, large metal builds proved unrestricted in metal type. From a design perspective, metal builds seemed to have greater capacity for handling complex form. Ultimately, a significant 65-80% timesaving was reflected in the production of metal components. However, the issue of high cost was set off against non-monetary advantages such as quality and reduced risk management. Therefore, producing large components via RP showed that the process was competitive with traditional manufacturing routes and therefore a viable option for the established sculptor to consider.

An advantage of RP technology is that complex entwined forms are built at the same speed as a solid cube of the same size; however, finer resolution machines do build slower. Current material and machine running costs remain an element of this technology that renders its status exclusive. However, as the industry grows and technology develops, costs will align with traditional manufacturing processes. Generally, for sculptors, CAD tools and RP processes are slow in being adopted as new technology because users are generally resistant to change, learning the program is a time-consuming process and most future users will wait until the current technology becomes outdated before changing over (Sequin, 2005). For the medium of digital sculpture, these factors play a role in impeding the accelerated development of this “new form” of sculpture delivery.

6. SCULPTURE: AESTHETIC CONCERNS SURROUNDING 3-D CAD AND ADDITIVE FABRICATION TECHNOLOGIES

The aesthetic focus of this article outlines issues such as authorship, authenticity and originality, which are concerns that encompass the use of the medium in a way that differs from what has sculpturally gone before. The 3-D build of digitally designed sculpture is a practice where technologically advanced “new form” and medium bring with it alternate aesthetic considerations regarding authenticity. One such aesthetic consideration would be to investigate the medium as a “new form” of production as opposed to a reproduction process alone. Koed (2005) expands on this aesthetic shift in his prediction that “the diverse characteristics of the contemporary art world might undermine theories of the nature of sculpture that appeal to particular physical properties of materials, or the involvement of specific perceptual modes, phenomena, or sensibilities, as criteria.”

At present the RP build of sculpture is met with much of the same scepticism as was the onset of photography (Lovejoy, 1990), because of a similar loss of human-connectedness and the question of originality. Fifield (1999) comments on originality and the copy by stating “[...] when 3-D photographic reproduction achieves the economic level of print reproductions, sculptors will face much of the same issues as printmakers did when the copy machine first appeared.” He also remarks that with this change of concept, issues about meaning and multiplicity in sculpture will grow. Wai (2001) postulates on the issue of multiplicity by claiming that if RP continues being limited to the production of presentation models alone, it will continue to be regarded as a limitation when compared to traditional modelling techniques. Presently, this concern is at the forefront of technological development and, as previously noted, the RP industry has significantly shifted its interest to RM, thereby encompassing future aesthetic issues surrounding multiplicity.

Currently the 3-D reverse engineering scanning process is one of the most commercially utilised tools for capturing 3-D form to a digital format, from which multiple reproductions of varying size can be reproduced via RP technologies. Ellen Thornton (2001), a legal specialist, claims that an aspect of digital copying to consider is that once the form has been scanned, the “copy” now consists of binary data bearing no resemblance to the original. Current South African legislation protects artistic feeling and the original material character of an artwork; it could be difficult to defend this claim in the case of a digital artwork. However, as the concept of copying forms the bases for any infringement, for the moment it also includes the mode with which it is stored. This therefore potentially weakens the argument that binary data as a transformed character of the original would not be deemed a copy (South Africa, 1978).

As postmodern perspectives blurred distinctions between original artworks and copies at the onset of “appropriation art”, copyright and authorship issues

have continued to be at the forefront of artistic debate. The 3-D RP build of sculptures via AF too, push the boundaries of authenticity and originality within existing definitions of sculpture. This is displayed in the current unlimited RP build and virtual display capabilities of digital sculpture, which are encased with extended meaning by way of its ubiquitous nature.

When the envisaged display moves beyond the 3-D virtual environment to a fixed RP 3-D build, one would assume that the sculpture displayed as a tangible, fixed object requires less debate than a virtual object as laws are easier to apply. However, this “new form” of sculpture delivery has copyright protection issues of its own to consider. The most significant would be the ubiquitous nature of the file data of a digitally designed sculpture, which is easily transported via electronic network to any RP station for the envisaged 3-D build thereof. An aesthetic viewpoint surrounding the concern of ubiquity introduced by Mandelbrojt, Frémot and Malina (1999) draws an interesting analogy of technological art by viewing it as “[...] equivalent to the traditional concept of durability and lastingness, with the infinity of space replacing the infinity of time [...]”. This thought can be considered as a fulfilling aesthetic prospect; however, within a legal situation one is still left with the nature of the file data presenting an object with no fixed original and unlimited reproducibility.

When analysing the vast abilities of digital sculpture, Rees (1999) speculates on authorship and the possible outcome of future software programs specifically designed to facilitate the creative process by stating that “[...] if sculpture became the agent of ubiquitous computing, then it also becomes the originator of the content and the controller of the context in which it gets interpreted.” With all these concerns in mind, a possible hurdle that most mainstream critics and practising artists encounter when confronted with this technology is that it challenges their imbedded consciousness about whether it is sculpture.

7. CONCLUDING COMMENTS

Indications illustrate that irrespective of current strengths and weaknesses, for the evolving sculptor, an interactive creative partnership between art and engineering technologies equally positions this “new form” of sculpture delivery as a leading role player towards defining a new digital aesthetic. Appealing properties such as infinite dissemination, multiple reproducibility and new material redefine the function and reception of digital sculpture on both aesthetic and technical levels. When applying these properties to artistic form and content, challenging unresolved aesthetic debate surrounding authenticity, copyright and authorship surface.

The establishing of an interactive creative partnership between the two disciplines determines the “way” and “means” digital sculpting intersect as a medium of artistic representation. It is therefore evident that a sculptor's user

requirements prior to engaging in these technologies need to include a sound understanding of available AF output material builds, their technological parameters, skill of an appropriate input mode(s), structural elements associated with 3-D form as well as an understanding of the aesthetics of conceptual design. This expanded set of 3-D design requirements clearly indicates that conventional 3-D art and design training collectively is in need of a shift to accommodate developing technical and aesthetic requirements.

8. THE WAY FORWARD

The technical manipulation of 3-D form increasingly occurs through applications such as virtual reality headsets and electronic data gloves. Compared to the familiar “haptic device” sculpting mode, these too rely on sensory and technological elements. Therefore, the aesthetic exploration of “user” interactivity as an advancing sensory mode of technology necessitates critical aesthetic research in order to define 3-D digital artistic interactivity.

An engaging approach towards forging a creative partnership through multivalent artistic activity within a “polycentric” world characterises the current activities surrounding digital sculpting. This approach has the potential of addressing telematic networking as the organisational framework for a transdisciplinary knowledge production of future digital design tasks. Simultaneously such interaction could present an institutional forum for developing a virtual faculty with student-teacher interaction over long distances as these technologies are at present largely based within educational institutions.

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